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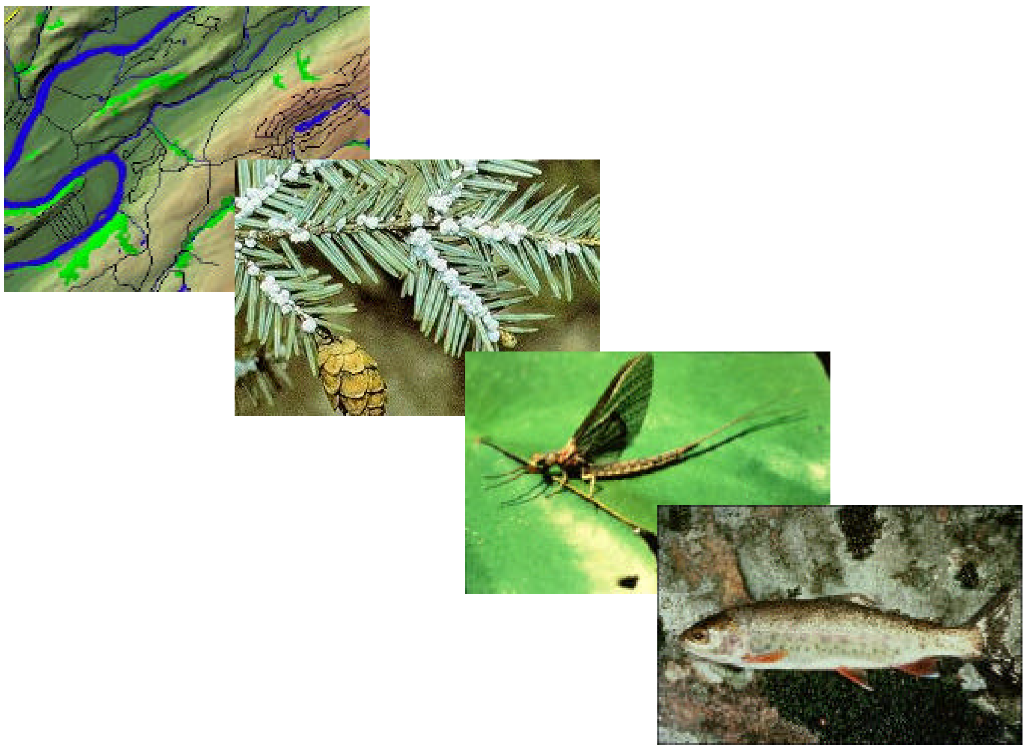
Influence of Eastern Hemlock on Aquatic Biodiversity in Delaware Water Gap National Recreation Area



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EXECUTIVE SUMMARY

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Eastern hemlock (*Tsuga canadensis*) occurs in cool, moist, hillside and ravine environments throughout the eastern United States (Harlow 1942). Hemlock stands and forests are valued as riparian and forest habitat (DeGraaf and Rudis 1986, DeGraaf et al. 1992) and as a commercial timber and horticultural species. Hemlock stands are also frequently targeted as desirable recreational areas on public lands because of their distinctive aesthetic, recreational, and ecological qualities (Evans 1995).

In the last two decades, substantial declines in eastern hemlock have been observed throughout its range, resulting in extensive Federal and state concern (Lapin 1994, Evans 1995). Widespread hemlock defoliation and mortality has largely been attributed to the hemlock woolly adelgid (*Adelges tsugae*, HWA), an exotic aphid-like insect that is native to Japan (McClure 1990). Resource managers expect the adelgid to continue to spread and consequently the entire hemlock forest ecosystem may be threatened. Recent studies suggest that hemlock regeneration following infestation is largely absent because smaller trees are at least as vulnerable to the pest as larger ones, and recruitment patterns in affected stands in Connecticut suggest hemlock forests will be replaced by mixed hardwood forests (Orwig and Foster 1998). A similar lack of regeneration occurred during the mid-Holocene when hemlock forests throughout North American went through a period of rapid, pathogen-induced decline (Fuller 1998). During that bottleneck, it took about 2000 years for hemlock to recover from the decline. Thus, there is a reasonable likelihood that forest stands killed by HWA will be lost indefinitely.

The impact of the removal of this important climax forest species on the ecology of Appalachian forests is poorly understood, but has the potential for significant disturbance to biotic communities by changing the energy inputs, micro-climatic environments, and physical habitat structure available to other vegetation, bird, mammal, and aquatic communities. Consequently, there is an urgent need to characterize the contribution of hemlock forests to biological diversity and functional stability in large, forested landscapes , and to identify contributing or ameliorating environmental conditions (both abiotic and biotic) that influence hemlock decline. Such information could provide the basis for future restoration strategies and serve as indicators of potential risk to hemlock forests not yet infested.

At the request of the National Park Service, the Leetown Science Center (LSC) conducted a comparative study designed to determine the potential long-term consequences to aquatic invertebrate and fish communities due to hemlock forest decline. We began by conducting a landscape analysis of the Park using Geographic Information Systems (GIS), and used the results to select 14 hemlock and hardwood site-pairs that were similar in topography (i.e., slope, terrain shape, aspect, light levels) and stream size but differed in forest composition (hemlock vs mixed hardwood). This paired watershed approach provided a powerful means to discern the influence of hemlock forests on stream communities, and provided an aquatic perspective on what we stand to lose in terms of biological diversity, should hemlock forests die.

We found aquatic invertebrate diversity to be strongly influenced by forest composition. Specifically, streams draining hemlock forests supported on average 37% more taxa than streams draining hardwood forests, though the significance and magnitude of the forest effect depended on stream type (as determined by terrain characteristics and stream size). In addition, 10% of invertebrate taxa encountered in DEWA occurred significantly more often in streams draining hemlock. In contrast, total invertebrate densities and the probability of occurrence of rare taxa were higher in streams draining hardwood forests. Trophic composition also differed between forest types with hemlock-dominated watersheds supporting more predators and fewer scrapers (algivores). This suggests that stream ecosystem function (e.g., rates of nutrient and carbon processing) might also differ between forest types.

Our inferences regarding forest effects on fish communities are less clear because a significant number of selected stream sites dried up during the summer of 1997 compromising sampling and statistical analyses. Nevertheless, based on more descriptive comparisons, it appeared that both fish diversity and abundance were higher in streams draining hardwood forests. In contrast, there was relatively convincing evidence that the occurrence and abundance of brook trout (*Salvelinus fontinalis*), an important fishery in DEWA, were higher in streams draining hemlock. For example, brook trout were nearly three times more likely to occur in streams draining hemlock forests. As with aquatic invertebrates, streams draining hemlock supported more predator species (largely due to more trout).

Analysis of instream habitat data indicated no single habitat variable directly correlated with aquatic invertebrate diversity or brook trout abundance differences observed between forest types. However, we found forest composition had a significant, concomitant influence on several habitat variables, each of which could have contributed to differences in aquatic community structure. Specifically, habitat diversity was higher, total nitrite concentrations lower, and temperature and flow patterns more stable in streams draining hemlock than in those draining mixed hardwood forests. Although the greater variety of microhabitat types and lower total nitrite concentrations observed in hemlock-drained streams may have contributed to aquatic community differences, we believe that hemlock mediated increases in thermal and hydrologic stability were probably most important in explaining higher invertebrate diversity and brook trout abundances.

In summary, we predict a significant reduction in aquatic invertebrate diversity and brook trout abundance in DEWA should hemlock forests succumb to HWA. From a broader perspective, lower invertebrate diversities in these small streams would likely result in measurable reductions in diversity park-wide, and may cascade to other assemblages, both aquatic and terrestrial. Furthermore, the observed hemlock effects on stream conditions may have a significant influence in other parts of the drainage basin as well. For example, hemlock-mediated increases in thermal and hydrologic stability may affect habitat in the Delaware River. Survival and productivity of Delaware River fishes, particularly trout and shad, may be limited by the relative severity of summer, base-flow conditions. Stable discharges of cooler water from hemlock-dominated tributaries may provide refugia for some species during these summer extremes.

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